Hybrid Surgery Techniques for the Treatment of Critical Limb Ischemia

An overview of combined open surgical and endovascular approaches to managing limb-threatening multilevel disease.

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Extensive multilevel atherosclerotic disease is common in patients with critical limb ischemia of the lower extremities.[1] It is frequently associated with multiple medical comorbidities, resulting from disease in distant vascular territories and making these patients high risk for extensive open surgical procedures. The alternative of hybrid revascularization surgery combines the well-established patency benefits of open vascular surgery with the advantages of less-invasive endovascular interventions to provide a durable and safe solution that can be customized to individual patterns of disease.

With the widespread adoption of fixed imaging systems within the vascular operating room and the developing endovascular skills of the vascular surgeon, patients now benefit from all-in-one procedures that are part open vascular surgery and part catheter-based intervention, so-called hybrid surgery. These procedures are often performed by a single vascular specialist under a single anesthetic in a single location, with clear patient benefits attributable to that simplified approach and cost savings of almost 50% compared to staged procedures in different locations.[2]

Several revascularization permutations exist for the hybrid procedure. In broad terms, they can be separated into surgical bypass or thromboendarterectomy in combination with a catheter-based intervention to improve inflow or outflow. Although individual anatomic and other patient factors will determine the most suitable combination of endovascular and open surgery, it is our experience that it is useful to divide multilevel disease into anatomic levels when considering the best approach. We then determine the most appropriate treatment type for each level and, through that delineation, form a concise strategy to complete those procedures during a single operation. This facilitates a complete and durable revascularization while minimizing unnecessary patient movement between procedural settings.

INFLOW PROCEDURES

Achieving optimized vascular inflow has historically been achieved with open surgery. Aortoiliac, aorto(bi)femoral, and femorofemoral bypass are durable but invasive and associated with considerable early mortality and morbidity.[3,4] In a systematic analysis pertaining to aortofemoral and aortoiliac bypass, de Vries et al found that primary patency at 5 and 10 years was 91% and 86.8%, respectively; however, the major morbidity rate was 19.7%, with 4.4% of patients dying within 30 days of the operation.[3] Sexual dysfunction is also an important and often overlooked complication, which was found in as many as 40% of men.[5,6]

The global movement toward less-invasive revascularization procedures has led to a paradigm shift in the treatment of aortoiliac disease, in which angioplasty and stenting have now become first-line treatment for most aortoiliac lesions.[7] The Inter-Society Consensus for the Management of Peripheral Arterial Disease (TASC II) guidelines documented the pooled results of 2,222 iliac artery angioplasty procedures for claudication (76%) and critical ischemia (24%), finding a technical success rate of 96% and 1-, 3-, and 5-year primary patency rates of 86%, 82%, and 71%, respectively.[8] In another single-center study that described a contemporary experience of 505 aortoiliac lesions treated with angioplasty and/or stenting over a 9-year period, a technical success rate of 98% was found, with 8-year primary and primary assisted patency rates of 74% and 81%, respectively, illustrating the durability of those procedures.[9] The safety of percutaneous interventions in this vascular territory was also clearly demonstrated with a 30-day mortality rate of 0.5%, which compares favorably to open surgery.[10]

In contrast, common femoral endarterectomy remains an exception to the ongoing trend favoring less-invasive treatment.[11,12] It remains the preferred technique for dealing with the common femoral artery, largely due to its proven durability, straightforward surgical access, and desire to maintain the common femoral artery for future percutaneous access (Figure 1).[11,12] Furthermore, the endovascular options for this region are often challenged by the tendency of the disease to form bulky, eccentric plaques that frequently involve the femoral bifurcation.

With acceptance of endovascular interventions for inflow procedures, several authors have gone on to evaluate their experience with endovascular inflow treatment of the aortoiliac segment combined with open vascular surgery for infrainguinal arteries. Piazza et al examined their experience treating patients with concomitant iliac and common femoral artery occlusive disease at a single institution over a 10-year period with both hybrid (84 limbs) and purely open surgery (164 limbs). The hybrid surgery population was older and had significantly more comorbidities; however, they had similar technical success rates (99% vs 99%), morbidity (3% vs 5%; $P = .55$), mortality (1.1% vs 1.4%; $P = .85$), and 3-year primary patency rates (91% vs 97%; $P = .29$) as compared with those treated with open vascular surgery. Furthermore, their hospital and intensive care unit lengths of stay were considerably shorter (3.9 vs 9.4 days; $P = .005$).[13]

Nishibe et al demonstrated acceptable results of hybrid approaches to the inflow segment, in which endovascular revascularization of the aortoiliac segment was combined with surgical endarterectomy of the common femoral artery in 21 limbs. Both simple

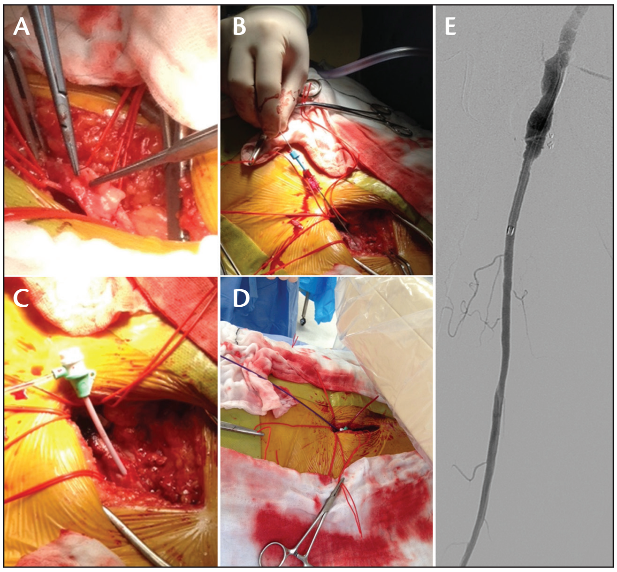

Figure 1. An open surgical femoral endarterectomy procedure (A), followed by the insertion of a 6-F sheath through the saphenous vein patch (B, C), introduction of wire and catheter (D), and completion of an angiographic femoral artery stenting procedure (E). A simple Z-suture technique was used to close the patch arteriotomy.

TASC A/B lesions and more complex TASC C/D lesions demonstrated acceptable patient and limb survival outcomes.[14] During a mean follow-up of 357 days, primary patency was 94%, 70%, and 70% at 6, 12, and 24 months, respectively.

OUTFLOW PROCEDURES

There are a number of well-described catheter-based techniques for the outflow segment after proximal open revascularization surgery. The choice will be determined by the open surgery performed and the level, as well as the pattern of disease and indication for treatment. The aim of a hybrid approach in this territory is to once again minimize patient morbidity while continuing to provide a durable revascularization. It has been our experience that certain patterns of outflow disease lend themselves to endovascular therapy, which in turn allows the operator to avoid the need to find lengthy bypass conduits and make extensive lower limb incisions.

Complex common femoral artery disease may be managed with local endarterectomy with or without profundaplasty, in conjunction with endovascular techniques for the femoral, popliteal, and/or crural artery outflow (Figure 1). These approaches allow for the preservation of the profunda femoris artery while avoiding the wound complications and lymphatic

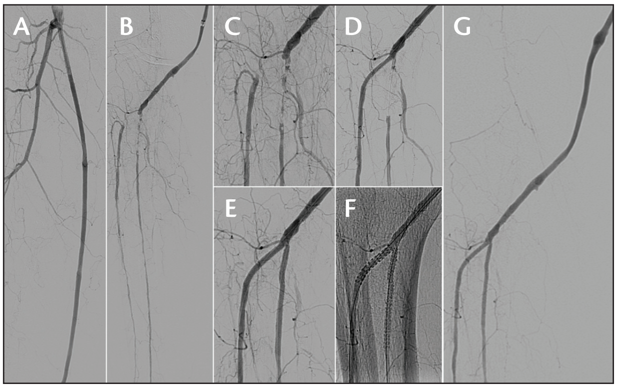

Figure 2. An open surgical femoropopliteal bypass procedure (A) in a patient with limited length of autogenous conduit. The bypass was followed by the angiographic imaging of significant outflow disease at the popliteal bifurcation (B, C). These proximal outflow vessels were stented in sequence; the anterior tibial followed by the tibioperoneal trunk (D–F). The completion subtraction angiogram shows significant improvement in the outflow vessels after bypass surgery (G).

disruption, which can occur after lower limb bypass. Another approach is to perform open surgical bypass of the femoropopliteal segment in combination with crural angioplasty/stenting (Figure 2). This option may be particularly useful when a sufficient length of venous conduit is not available. Moreover, it may allow the operator to visualize optimal blood flow to the wound-related artery and intervene accordingly.

Antoniou et al retrospectively analyzed their entire hybrid experience, of which 24 limbs had undergone hybrid surgical procedures, which combined proximal revascularization surgery with outflow angioplasty and stenting.[15] The most common procedure performed was femoral bifurcation endarterectomy combined with distal angioplasty or stenting of the superficial femoral artery (SFA), popliteal, or infragenicular arteries. Excellent technical success and respectable patency rates comparable to other endovascular studies were achieved, and no restenosis at the femoral endarterectomy sites was observed.

COMBINED INFLOW AND OUTFLOW PROCEDURES

Multilevel inflow and outflow disease of the critically ischemic limb has been treated using a combination of the aforementioned approaches. After the success achieved with hybrid surgery of both the inflow and outflow vessels, several authors have combined the one-stage treatment of both vessels with open revascularization surgery used to treat only the mid-segment. Dosluoglu et al describe the double PAGA (prearteriotomy guidewire access) technique in which inflow and outflow lesions are crossed with a catheter and wire after femoral artery exposure but prior to femoral endarterectomy.[16] Angioplasty and stents were used to treat the inflow and outflow lesions, with the operators then proceeding to complete the femoral endarterectomy as a final stage to the procedure. Three-year primary patency and complication rates were equivalent to open surgery rates despite more preexisting medical comorbidities in the combined procedure cohort.

Cotroneo et al evaluated their experience with complex multilevel disease over 2 years. They performed common femoral endarterectomy and/or bypass surgery combined with interventional treatments of either the inflow, outflow, or both. The 2-year primary patency rate was 79.1%, with only two deaths in their cohort of 44 patients.[17] Late failure or restenosis occurred in three of 44 patients (6.8%), who in turn required further interventional or surgical treatment. There were no amputations in their study, despite more than 75% of patients having a Rutherford-Becker score > 3.

In our practice, we have found it preferable to perform femoral endarterectomy first, followed by iliac and infrainguinal revascularization. This approach facilitates a simpler endarterectomy and reduces the likelihood of interfering with recently placed stents, which may extend in close proximity to the common femoral artery. Furthermore, stents may be placed at the end of the endarterectomized segment, if required, where the transition between dissected plane and native vessel may be imperfect.

In the next section, we describe a complex hybrid procedure utilizing femoral endarterectomy and retrograde anterior tibial artery access in a patient with ischemic tissue loss.

CASE REPORT

A 75-year-old man with a history of smoking, prostate cancer, and ischemic heart disease presented to our institution with a right heel ulcer. CT angiography demonstrated heavily calcified occlusions of the distal external iliac artery, common femoral artery, SFA, and proximal popliteal artery, with anterior tibial and peroneal artery runoff to the foot (Figure 3).

A hybrid approach was used, whereby an iliofemoral endarterectomy was performed to remove the common femoral and external iliac artery plaque through a vertical groin incision. The proximal SFA was also endarterectomized, and a 6-F sheath (Brite Tip, Cordis Corporation) was then passed carefully into the SFA. The common femoral arteriotomy was partially closed in a primary fashion using 5–0 polypropylene suture, with the suture line snugged around the sheath and pulled tight for hemostasis.

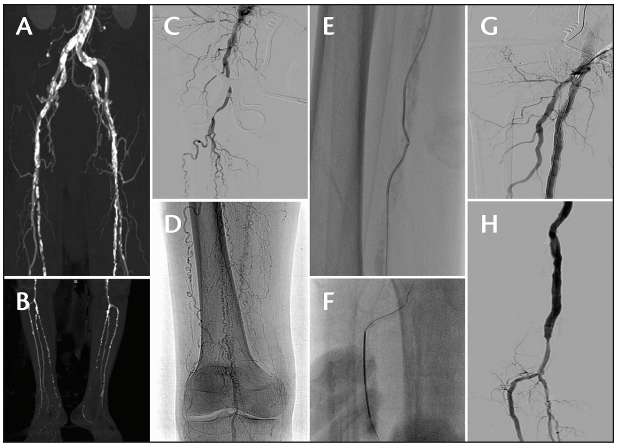

Figure 3. CT angiography demonstrating heavily calcified occlusions of the iliofemoral segment, SFA, and proximal popliteal arteries (A). Two-vessel runoff via the anterior tibial and peroneal arteries can be seen (B). After femoral endarterectomy (C), a 6-F sheath was placed through the suture line into the SFA. Antegrade wire passage to the reconstituted below-knee popliteal artery was attempted but unsuccessful (D). The wire was fed into the antegrade catheter in the mid-SFA (E) following retrograde proximal anterior tibial artery puncture (F). After nitinol stent insertion and postdilatation, the common femoral, SFA, popliteal, anterior tibial, and peroneal arteries were patent with brisk flow (G, H).

After surgical declamping, the SFA and popliteal revascularization were completed using a bidirectional wire access technique. The anterior tibial artery was punctured, and a retrograde wire was placed into the SFA, which was then externalized through the proximal sheath by passing it into the endhole of a Berenstein II catheter (Cordis Corporation) within the occluded SFA (Figure 3E). A 6-mm balloon predilatation was then performed, after which, the popliteal artery and SFA were lined with multiple 6-mm interwoven nitinol stents (Supera, Abbott Vascular) (Figure 3G and 3H). The anterior tibial artery puncture was then managed with remote balloon occlusion (3- X 20-mm Armada 14, Abbott Vascular) that was inflated at the site for 3 minutes.

OTHER CONSIDERATIONS

These procedures should be planned with adequate preoperative imaging and team discussion prior to embarking on definitive treatment. The physical location is an important consideration, as these procedures require the sterile environment and air filtration systems of an operating theater with the high-end imaging capabilities of a fixed angiographic imaging system or high-quality portable C-arm. In our experience, a modern-day hybrid operating room is the ideal environment to provide versatility and ensure best patient outcomes.

CONCLUSION

Hybrid vascular surgical techniques open up a world of opportunity for the vascular specialist. Rather than considering a patient in terms of suitability for open surgery or endovascular intervention, multilevel disease can be appraised on its merits, and each region can be treated with an approach that will best optimize outcomes and ensure safety for the patient as a whole. It is now commonplace in most advanced critical limb ischemia centers for multidisciplinary teams or vascular specialists trained in both open surgery and interventional techniques to utilize an individualized, hybrid revascularization strategy for patients with limb-threatening ischemia resulting from multilevel peripheral artery disease. ■

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